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## *THE AMERICAN ASSOCIATION FOR THE ADVANCEMENT OF SCIENCE*

## *PRINCIPLES OF PALEOGEOGRAPHY*[1]

### INTRODUCTION

THE science of the geography of past geologic periods, which is sometimes known as paleogeography, is a young science that has all its future before it. It springs from several older sciences: geography, geology, meteorology and paleontology; and in its development it must rest upon their general principles.

Paleogeography may be defined as the science of geography of all periods of the globe's history since earth, air, and water assumed those states in which they now exist. The science does not extend to any earlier state of the world. But from the time of the earliest lands, seas, and atmosphere to the present, the sequence of geographic conditions comprises the facts of paleography.

The science is very comprehensive. It includes not only the arrangement of continents and oceans and their individual features, but also the topography of lands, the circulation of oceanic waters and of the atmosphere, the climate, and the distribution of life, which were characteristic of the earth's surface during any particular epoch. It must trace the changes in these features from epoch to epoch, and with the aid of all allied physical and biological sciences, paleogeography should search out the ultimate causes which actuate the de-

[1] Address of the vice-president and chairman of Section E—Geology and Geography. American Association for the Advancement of Science, Boston, December 28, 1909.

velopment of the earth's superficial forms and of the earth's inhabitants.

The science of geography, as it is commonly understood, relates to a single geographic condition, that of the present. There have been many others in the past.

The present geographic condition or geography is peculiarly distinguished by large continents and high mountains, by extremes of polar cold; by great humidity of some regions and excessive aridity of others, and by corresponding diversities of faunas and floras. The geography of Quaternary time has been and is abnormally developed.

The geographies of the past have been individual also; sometimes, though rarely, they have exhibited extreme characters, equal in diversity of conditions to the Quaternary period; but as a rule extremes have been less pronounced and a nearer approach to simplicity of features has prevailed.

Could we at any past time have viewed the earth from without with an all-seeing eye, during any one epoch, we should have seen a single geography, a panorama. If we might have maintained our vigil from age to age during all her history as the globe, we would have observed the succession of geographies, a long procession.

In that procession we would have seen moving forward the great lines of evolution in the animate and inanimate world.

Slowly rising in response to the working of internal terrestrial forces, continents have emerged from the waters. Wasted by erosion they have in part been submerged again. Again they have risen and again sunk. The rhythm of their movement, the grand rhythm of the sphere, is timed to millions of years.

In comparison transient as the passing seasons of the year, mountain chains have grown under temporary though titanic stresses of the crust, and have wasted under the rays of the sun and drops of rain. Generation after generation of ranges has appeared, paused, and passed; incidents of the geographic procession, but integral features of it, obeying in time and place the law of its progress.

Atmosphere and ocean, those fluent envelopes of the sphere, have to outward appearance been least changeable, but they also have changed. Their currents circling westward against the revolving sphere and returning eastward, have adjusted their courses to the seas and lands. Subtly too the air and waters have been modified chemically as the critical constituents of the air and the soluble salts in the waters ran their changes in the laboratory of land and sea.

All of the changes suggested are linked in a chain of cause and effect, from continental movements to atmospheric circulation. Finally the evolution of living organisms is conditioned by them all. The life impulse, tending to develop new forms, has been helped or hindered by environment. Favored by congenial and widening habitats, faunas have diversified, become enriched, have spread, and attained cosmopolitan range. Or restricted to narrowing uncongenial districts, they have lost by extinction of the unadaptable elements and become limited to the surviving fittest. Had environment been unchanging, evolution would have run its course chiefly according to the intrinsic influence of the life-principle, but since environment has ever been changing, adaptation to modified external influences has played a dominant rôle.

The great procession of geographies, which has moved down the ages, has obeyed those laws of inorganic and organic change, which we recognize as the principles of

geography, geology, oceanography, climatology, paleontology and evolution. The principles of astronomy, physics, chemistry and biology are also involved to the extent that they enter into the development of geographic conditions.

Because paleogeography is thus comprehensive, no one investigator can adequately solve its problems. A group of students only can do the science justice. In attempting this statement of its general principles, I do not fail to recognize the fact that it must be incomplete and qualified by inadequate understanding of many of the branches of knowledge involved.

### PERMANENCE OF OCEAN BASINS

Oceanography is a science which as yet scarcely ventures over the threshold of the present upon the long vista of the past, but the guidance of paleogeography leads that way. From the study of ancient lands and epicontinental seas we are led directly to the recognition of ancient ocean basins; it is, however, particularly among European geologists, still a mooted question whether the hollows, which the waters occupy, have constantly existed as hollows or may have been sites of continents which have now sunken in. The evidence that the hollows have constantly existed is strong. Upon it rests an assumption, which must be either affirmed or denied, there being no third condition, and which may be stated in the affirmative form as a principle:

*The great ocean basins are permanent features of the earth's surface and they have existed, where they now are, with moderate changes of outline, since the waters first gathered.*

This conclusion rests upon three principal facts:

The continents have never been submerged to oceanic depths and consequently can not have been replaced by deep hollows.

The oceanic basins have always been of such capacity that they contained by far the larger part of the waters, which have overflowed on the continents only as relatively shallow epicontinental seas; hence no considerable part of the existing basins can ever have been occupied by land.

There is a relation between the intensity of gravity and the relative altitude of a continental or oceanic plateau, which proves that the plateaus have assumed different altitudes according to the densities of the subjacent material. The transformation of a continent into an ocean basin, or *vice versa,* would require, therefore, a change in density of an enormous volume of material, and there is neither evidence nor explanation of such a change.

A few words may be said in support of these propositions, but before doing so a distinction should be made between the great ocean basins and those deep troughs which have from time to time developed within continental plateaus and which Dana called geosynclines.

In their genesis ocean basins and geosynclines may have been similar; but in their dimensions, histories and structural relations they are radically different.

I will not dwell on the great magnitude of the Atlantic or Pacific basins in comparison with the Appalachian or Cordilleran geosynclines. They need but be named.

The history of a geosyncline comprises a prolonged stage of subsidence accompanied by more or less constant deposit of terrigenous or marine sediment, and often a further stage of compression, folding of strata and elevation as a mountain range.

The history of ocean basins does not exhibit a similar stage of subsidence within the eras of the geologic record, although the hollows have sometimes apparently

deepened enough to affect the extent of epicontinental seas. And no ocean basin has been compressed, crumpled and raised, after the manner of the Appalachians or Alps.

The structural relations of geosynclines are intra-continental, those of oceans are extra-continental. The geosyncline occupies a position among the positive continental elements. The oceanic basins separate and surround continents.

The distinction between geosynclines and ocean basins is thus fundamental, and to reason from the history of the one to that of the other, as has sometimes been done, is necessarily misleading.

This distinction noted, we may return to the proposition that the ocean basins have always been permanent since ocean waters gathered.

The evidence is clear and unquestioned that marine waters have circulated and marine faunas have migrated from epicontinental seas of the eastern or western hemisphere to those of the other hemisphere, and they could only have done so across or around bodies of water occupying the sites of the present oceans.

We have good reason to assume that the volume of oceanic waters has not changed materially from what it was at the inception of existing conditions, it being apparently true that contributions from within the earth have been relatively small during geographic eras, and none being known from without.

The ocean basins are now somewhat overfull; they are not large enough to hold all the waters, which therefore extend over the margins of the continents. During certain epochs of the past the waters have spread farther, the basins having then been less capacious; again during certain other epochs the waters have withdrawn into deeper or wider basins. These variations have lain within narrow limits as compared with the total volume of the oceans, and they have occurred repeatedly, in alternation. Had a continent ever existed in place of one of the ocean basins, it must on sinking to oceanic depths have produced a disturbance of these nicely adjusted relations, of which the geologic record shows no trace; which must, however, have been of such magnitude that it would have marked off an older era of small lands from a later one of great continents. No such event has taken place, and no continent of oceanic extent has sunk to oceanic depths.

This conclusion bears on the reconstruction of former continental extensions. If we accept the evidence that Appalachia formerly extended southeastward into the Atlantic, we must consider reasonable limits. If we erect a transatlantic land to connect Africa and South America, or postulate a Gondwana land from Africa to Australia, we must provide for the waters which such lands displace. The ocean basins and possible epicontinental seas are the only refuge for the waters which are thus hypothetically evicted, and their capacity may be overtaxed.

The capacity of a basin being affected by changes in depth or width, it is obviously possible to argue that narrower but deeper basins may formerly have contained the waters that are now held in wider and possibly shallower ones. To a certain extent this view may be entertained, but it has limits and they are close to present conditions. The average depth of nearly two thirds of the ocean's basins below the continental plateaus is 4,000 meters or more. At this difference of altitude the weight of the continental column crushes its base and creep ensues. The depth can not be materially increased without occasioning corresponding spreading and low-

ering of the continental plateau, till the present condition of approximate isostatic balance were reached.

The postulate of isostatic equilibrium among masses of unlike densities in the earth's crust has recently been strongly supported by the work of Putnam[2] and Gilbert[3] on gravity in the United States, of Hayford[4] on the deflection of the plumb line in the United States and of Hecker[5] on the attraction of gravity on the oceans.

Hecker puts the general conclusion thus:

> It follows that not only the superficial masses of the continents must be compensated by a defect of mass, a less density in the earth's crust under the continents, but also that there is compensation beneath the deep seas through the greater density of the ocean bottom.
>
> Inasmuch as it has been shown that Pratt's [Dutton's] hypothesis of the isostatic relations of masses holds not only for the continents, but also for the three oceans (Atlantic, Pacific and Indian), we may regard it as a law which, apart from certain disturbances, is a general one for the earth's crust.

This conclusion appears to place the permanence of ocean basins outside the category of debatable questions.

A conclusion which follows closely from that of the permanence of oceans, is the *constancy of the major oceanic drifts or currents from an early date in each of the great oceans.*

Movements of ocean waters result from winds and differences of density of the waters. The trade-winds and their complements, the westerly winds of higher latitudes, are due to causes which have existed since the atmosphere and oceans formed; to rotation of the earth and to the distribution of the sun's heat. These causes operating through the winds on water bodies of oceanic dimensions must have always produced an east-to-west equatorial current, which being diverted by continents, developed great circulatory movements in the several ocean basins, flowing clockwise in the northern hemisphere and anti-clockwise in the southern. On the basis of the arguments just presented, the ocean basins are permanent, and hence the great superficial oceanic currents which characterize them must be regarded as equally ancient in their main features.

This conclusion regarding superficial currents does not necessarily apply to the deeper circulation, and there are reasons for believing that the latter is now abnormal. The deep-seated circulation is occasioned by differences of density or head, dependent upon temperature, salinity, precipitation and heaping of the waters by wind. Chamberlin[6] has suggested the analysis of these factors and has brought out the possibility of a change in the equilibrium of the waters, which may have resulted in *warm highly saline currents flowing poleward from the equator, beneath cool relatively less saline currents flowing toward the equator;* the reverse of the present condition.

The density of polar waters is attributed primarily to cold, and, as Chamberlin points out, may be increased in those regions where ice forms and where there are no large rivers by the salts forced out of

[2] Putnam, G. R., "Results of a Transcontinental Series of Gravity Measurements," *Phil. Soc. Wash. Bull.*, Vol. XIII., pp. 31–60, 1895.

[3] Gilbert, G. K., "Notes on Gravity Determinations by Mr. Putnam," *ibid.*, pp. 61–76, 1895.

[4] Hayford, J. R., "The Figure of the Earth and Isostasy," U. S. Coast and Geodetic Survey, 1909.

[5] Hecker, O., "Die Schweresbestimmung an der Erdoberflache und ihre Bedeutung für die Ermittelung der Massenverteilung in der Erdkruste," *Zeitschr. der Gesell. für Erdkunde*, Berlin, No. 6, 1909.

[6] Chamberlin, T. C., "On a Possible Reversal of Deep-sea Circulation and its Influence on Geologic Climates," *Jour. of Geology*, Chicago, Vol. 14, 1906, p. 363.

the superficial layers in freezing. Were the more profound causes of the climatic state so modified as to ameliorate the severity of polar cold, both of these influences would be moderated, and the effects of freshening by rivers and precipitation would not be offset to the extent that they now are.

On the other hand, equatorial waters are warmed and evaporated, and they are thus rendered light because warm, yet heavy because saline. The actual density, as compared with that of polar waters, is now less than the latter, but both observation in the oceans and calculation show that the balance is small. Were the polar waters less chilled or more freshened or both, the equatorial waters would be heavier, and the reversed circulation suggested by Chamberlin must result.

The cold of the present polar climates is extreme and unusual. To whatever fundamental causes we may attribute it, we know that it did not exist during the Miocene, Eocene, Cretaceous, later Jurassic, Carboniferous, Devonian, Silurian, Ordovician, or later Cambrian. Frigid conditions may have occurred with severity in the earlier Jurassic or Triassic and in the early Cambrian or late pre-Cambrian. That is to say at periods which, like the present, were periods of exceptional continental expansion and elevation. It seems to follow cogently that the condition of oceanic circulation which depends upon polar cold is also exceptional. Under more genial conditions, the waters in high latitudes would be lighter than now because warmer. They would also be more generally freshened by precipitation, and nowhere rendered more saline by freezing. The conditions which now occasion the greater density of polar waters would thus fail and the balance would sink on the side of the equatorial waters. Heavier equatorial, lighter polar waters have probably been the normal condition; the reverse, which now exists, the abnormal.

This conclusion follows entirely apart from the consideration that the extraordinarily mild climates of some ages are rendered less difficult to understand if the deep-seated circulation of the ocean were thus reversed, if it had normally been a movement of warm waters in the depths, instead of at the surface, toward the pole. But the facts, which it explains, strengthen the hypothesis and place it in the front rank of important suggestions in the study of paleogeography.

### PERIODICITY OF DIASTROPHISM

Diastrophism, the process which comprises all movements of the earth's crust that modify continents or give rise to mountain ranges, has been characterized by periods of activity in alternation with periods of quiescence, throughout all geologic history.

This principle of the periodicity of earth movements rests upon the observation that periods when continents emerged from the sea and became mountainous have alternated with periods when continents had become low and were extensively submerged.

The emergence of continents and the growth of mountains are due to activity of the internal terrestrial forces; the reduction by erosion to low lands and the resubmergence mark the period of inactivity. The Quaternary is a time of decided activity, resulting in large continents and great mountain chains. It has been preceded by times of relative quiescence and by others of greater movement, in alternation, as far back in the past as the record goes.

While geologists in general will agree that this is a true principle, they find it

more difficult to define the respective periods.

It is possible to recognize at least three grand cycles from late pre-Cambrian time to the close of the Mesozoic, each grand cycle consisting of a long period of activity and a still longer time of relative quiet, thus:

| | |
|---|---|
| Late pre-Cambrian activity (apparently somewhat general),<br>Cambrian and Ordovician inactivity (general), | $n$th cycle. |
| Silurian and Devonian activity (qualified by circumpolar quiet in the north),<br>Late Devonian and early Carboniferous inactivity (general), | $(n+1)$ cycle. |
| Later Carboniferous and early Mesozoic activity (non-contemporaneous in different dynamic provinces),<br>Later Mesozoic and early Tertiary inactivity (general), | $(n+2)$ cycle. |

Later Tertiary and Quaternary then constitute the initial, active period of the $(n+3)$ cycle.

While these grand cycles may be recognized for the whole world as far as we know the facts, it is found that each one may be divided into epicycles consisting of shorter periods of emergence and submergence *especially if attention be fixed upon a single ocean basin and the continents adjacent to it.* The North Atlantic, for instance, is bounded on the east and west by lands, which have been disturbed or have been at rest during the same epochs, and the several cycles have been of much shorter duration than those enumerated above for the whole world. These cycles are indeed those on which the time-scale of geologic history is based, and each one corresponds in general with a standard period, Carboniferous, for example.

Lands about the Arctic Ocean did not share in the Atlantic movements of Silurian, Devonian or late Paleozoic epochs. On the contrary, the great epicontinental seas of those periods were circumpolar. Nor do lands about the North Pacific, from California to China, record a history parallel with that of eastern North America and northwestern Europe, with the Atlantic history. In the Atlantic provinces, the Paleozoic era closed with marked diastrophism, while comparative tranquillity reigned around the Pacific; but the Pacific provinces were greatly disturbed in the middle Mesozoic when quiet had supervened about the Atlantic. Again, a distinct series of movements is recorded in the great geosyncline of Eurasia, that which stretches from India to Spain and is now marked by the system of mountain chains of which the Himalaya and the Pyrenees are the extremities. Similar movements appear to characterize the West Indies and northern South America. If, as I believe, these parallel movements in Eurasia, South America and the Indies originated in a common dynamic region, then that region is the great ocean of the southern hemisphere, including the South Atlantic, the South Pacific and the Indian oceans.

The principle of periodicity is necessarily qualified by these facts and the general law should be supplemented by one which recognizes unlike dynamic histories of different oceanic regions. It may be stated thus:

*The phenomena of diastrophism are grouped according to several distinct dynamic regions. Each region has experienced an individual history of diastrophism, in which the law of periodicity is expressed in cycles of movement and quiescence peculiar to the region. The cycles of one region have been, however, to some extent parallel, though not conterminous, with the cycles of other regions, and thus major cycles of world-wide condi-*

*tions are constituted by coincidence of regional conditions.*

The periodicity of diastrophism is the fundamental fact of geographic history. It carries with it corresponding periodic effects, both direct and indirect, in erosion, sedimentation, climatic changes, and even in organic evolution. All of these processes depend upon the initiative action of the earth's internal energy and they all are rhythmic because its action is rhythmic. Thus this general principle gives rise to correlative principles, which may be stated independently for each of the processes.

## PERIODICITY OF EROSION AND SEDIMENTATION

American geologists need no restatement of the phenomena of cycles of deposition and erosion which Newberry[7] emphasized and which have led through the work of Powell, Gilbert and Davis to recognition of the principle that epochs of marked relief and vigorous erosion have alternated with periods of base-leveling, and that sediments have alternated correspondingly in character and volume. I may pass the subject of base-level periods and orogenic epochs as related to erosion and sedimentation with this reference to it, mentioning only that it is the essential principle in Chamberlin's[8] latest contribution to the philosophy of correlation; but though the principle is accepted there is still occasion to dwell upon *the constancy of erosion and the inconstancy of sedimentation*, especially since the facts may be the reverse of what is sometimes assumed and since they lie at the foundation of our interpretations of the geographic record.

[7] Newberry, J. S., "Circles of Deposition," Amer. Assoc. Adv. Sci., *Proceedings*, Vol. 22, pt. 2, 1874, pp. 185–196.

[8] Chamberlin, T. C., "Diastrophism as the Ultimate Basis of Correlation," *Jour. of Geol.*, Chicago, Vol. 17, 1909, pp. 685–693.

It is assumed in some instances that erosion on supposed subaerial surfaces has either not occurred or has left no traces, whereas on the other hand the surfaces, if they had been submarine, must invariably have been covered with sediment, which would constitute a record. And the conclusion is drawn that sections which exhibit an incomplete sequence of strata must have been land areas at certain times. It is a hazardous conclusion in the absence of definite evidence of erosion, for subaerial processes never fail to leave some kind of mark, and submarine processes are consistent with non-deposition.

*Constancy of Erosion.*—The atmosphere is never at rest. Wind, rain and snow; heat and cold; moisture, carbonic acid and other chemical agents; all these have ever worked unceasingly, according to the circumstances that condition them, upon exposed land surfaces. No land has ever been exempt from their attack, which results in decay, denudation or aggradation, as the case may be.

Decay, denudation and aggradation are processes of erosion which invariably leave chemical or mechanical evidences of their activity. There is to-day no surface of any land, however high or low, under any climate whatever, which does not bear indubitable marks of one or the other of these processes. There is abundant evidence that they have been at least equally active and effective during past ages and that they have marked ancient lands as they do those of to-day.

We frequently recognize ancient land surfaces on evidence of soils, wear or subaerial deposits. Or, if they have passed through processes, such as marine transgression, that destroy the earlier effects, we observe the sequence of changes and reason back to the corresponding conditions. But there are seemingly continuous sections

which are nevertheless apparently less complete than others in adjacent basins and which seem therefore to have been areas of non-deposition. Even if the hiatus be real, and not merely supposititious, it does not follow that non-deposition has been a subaerial condition. Such anomalies of non-deposition occur characteristically between strata laid down during periods of wide-spread marine transgression when lands were low and covered with residual or alluvial deposits. If any area was raised higher during the interval, it must have been correspondingly corraded. And if the evidences of decay or corrosion are wanting the postulate of a land area corresponding to the region of non-deposition should be regarded with much doubt.

*Inconstancy of Marine Sedimentation.*—It is commonly assumed that sediment of some sort necessarily accumulates over the bottom of a marine basin and that this has always been the case in epicontinental seas of all ages. Consequently non-deposition is not considered and special hypotheses of uplift and subaerial erosion are devised to account for the absence of strata which might or should have been deposited. Yet non-deposition and even the scouring of bottoms so that hard rock is exposed are conditions of modern sea bottoms where they are swept by currents whose load is less than their efficiency.

Verrill has described the coarse shifting sands of the New England coast, which are kept in such constant motion by tidal currents that no life finds lodgment on them. The whole continental platform from Long Island to Hatteras is so swept that sand alone comes to rest, all finer sediment being carried on to the zone of oceanic ooze.

Agassiz found hard limestone bared of any deposit except serpularia and similar clinging organisms beneath the silt-laden Gulf Stream, where it flows across the epicontinental platform, between Florida and Cuba. Among existing seas and straits this instance is one which, in the conditions for marine scour, most nearly resembles the epicontinental seas of past times.

Between Scotland and the Faroe Islands stretches the Faroe Island ridge, a wide stony bar between the North Atlantic and the Arctic basins. Its crest lies 300 fathoms below the surface of the ocean; yet it is swept clean, while banks of ooze accumulate on the slopes north and south of it.

The present distribution of lands and oceans is unfavorable to marine scour and favorable to deposition. Epicontinental seas are confined to the margins of continental platforms, to which high lands contribute abundant sediment, or they are deeply embayed and shut off, as Hudson Bay is. Non-deposition is therefore an exceptional condition. We may grant that it has always been restricted to comparatively shallow waters, in the path of a relatively strong marine current. But the epicontinental seas of the periods of great marine transgressions (Cambrian, Ordovician, Silurian, Devonian, Mississippian and Cretaceous of North America for instance) opened channels across the continent, through which oceanic currents circulated as the Gulf Stream flows from the Caribbean to the Atlantic. Low lands bordered these seas and the deposits which accumulated in the deeper basins consisted in great part of fine calcareous ooze. Under these conditions non-deposition and marine scour have been favored on shallows along shores and in straits, and in any such places a corresponding hiatus must occur in the stratigraphic sequence.

In paleogeographic study it is important, therefore, to consider the principle that marine waters may not only deposit sediment, but may also prevent deposition, or even remove a deposit previously made.

PRINCIPLES RELATING TO CLIMATE

The history of past climates affords problems which are among the most obscure of paleogeography.

On the one hand climate at any particular epoch has been determined by the distribution of land and sea and the corresponding movements of the winds and positions of the great cyclonic and anticyclonic centers. Given a map showing the oceans and lands of the northern or southern hemisphere, the climatologist may apply the principles deduced from the present relations of atmospheric activity to surfaces that affect the temperature of the atmosphere in different degrees and he may arrive at a reasonable conclusion in regard to the distribution of temperatures and precipitation.

Such a conclusion is based, however, upon existing climatic conditions and can be only a rough qualitative approximation to the very different conditions of earlier ages. The geologic record yields abundant evidence to show that our present climates are unusual in the extreme differentiation of climatic zones. No previous age offers evidence of equal polar refrigeration, and none has as yet shown proof of deserts of equal extent and general distribution. On the contrary, it would seem that climate in the past has been generally more uniform from pole to pole and around the earth than it is now.

We may attempt to explain this result of observation by recognizing that the present diversity of climates is connected with extreme conditions of mountain growth. Mountain ranges are to-day more general and of greater altitude than they have commonly been in the past and the condition of the low lands, which has at times prevailed over the greater part of the continent, has been favorable to uniformity just as the converse is favorable to diversity of climate. But this explanation falls far short of satisfying the requirements of the problem.

We may supplement the reasoning by appeal to the reversal of oceanic circulation suggested by Chamberlin as a possibility in view of the fact that equatorial saline waters, even though warm, might under certain conditions become denser than fresher polar waters, even though these be cold, and thus warm waters sinking in the equatorial regions and flowing toward the pole would carry with them the higher temperatures of the tropics and produce more genial climates in the polar regions. This suggestion is extremely attractive, and has a high degree of probability, particularly when we consider that the present circulation of deep-lying cold waters is largely due to the polar ice-caps, which are themselves extraordinary features. There is reason to believe that the present oceanic circulation is abnormal and the reversed circulation suggested by Chamberlin has in past ages been the normal condition.

In recognizing the effectiveness of low lands and reversed ocean currents to produce uniformity of climate such as the geologic record requires, we arrive at a working hypothesis which satisfies the immediate condition of certain climates that characterized great periods of the earth's history; but we are yet far from an understanding of the processes which underlie the change from one condition of climates to another. There is some general cause, so subtle that it has as yet eluded distinct recognition, which affects the conditions of climate more deeply than the local phenomena suggest. It has been approached by theories along astronomical lines and by a single theory which connects climate with the earth's internal forces.

The astronomical causes may be shown

to have an essential relation to climate, but at present I believe we can not fairly say that that relation has been shown to have existed. On the other hand, there appears to be a definite connection between the physical geography of the earth's surface and the climate of any corresponding epoch. Large continents and high lands have been associated with diversity of climate; small continents or archipelagoes and low lands have been associated with uniformly genial climates. Moreover, the chemical reactions between rock masses exposed to weathering and the critical constituents of the atmosphere and the seas, such as carbonic acid and moisture, appear to establish a chain of phenomena, which involve temperature and humidity, and which affect the intensity of provincial climatic differences. In a broad and general sense we may refer to the periodicity of climatic change in the same way that we recognize periodicity of general diastrophism, and the cycles of the one appear to coincide with the cycles of the other. Chamberlin has recognized the relation and has endeavored to trace it through the critical influence of the small percentage of carbonic acid in the atmosphere. In following the course of that critical element from the air through the laboratory of the lands and seas back to the atmosphere, he established a chain of phenomena which is unquestionably a *vera causa* of the common periodicity of the phenomena.

We may conclude then that the study of ancient climates involves two connected problems. The first relates to the distribution of provincial climates according to the distribution of lands, seas and permanent oceans. It may be approached by applying the laws of modern meteorology to a preliminary solution. That solution must, however, be tested against the geologic and paleontologic evidence of the corresponding time, and must be qualified by conclusions based upon broader principles which involve the physics and chemistry of the atmosphere in its relations to land and sea. Through these the second problem, which involves the periodicity of climates, is to be approached.

EVOLUTION AND ENVIRONMENT

In the long chain of causes and effects initiated by terrestrial and solar energy, the development of life is the latest link. All that precedes life is characterized by change which moves in a series of cycles. Life, on the other hand, is characterized by change which has moved forward in progressive evolution. Upon this fundamental distinction we separate the inorganic from the organic and recognize the latter as pertaining to a higher phase of development.

Evolution is not, however, the only attribute which distinguishes life from the lifeless, for life is qualified by the further attribute of death. The individual, the species, the genus, the family and race, everything which lives, ultimately comes to the final end, and there is in the evolution of the organic no return of that which has thus died. While the inorganic world repeats, the organic world never does.

Profound as these distinctions are, they nevertheless do not emancipate the organic from the control of the inorganic. Life is inexorably conditioned by its environment. Through ages of evolution and adaptation, each individual is fitted to exist under a special set of circumstances which constitute his environment. Narrow limits are set to the capacity of the organism to adjust itself to sudden changes, and only within those limits can it continue to exist. Beyond them on all hands stands the inevitable death. In the history of the individual there are special periods of

development, such as infancy, youth and old age, when these limits are narrower than they are for the epoch of full vigorous development of the adult; and these sensitive periods are those which are critical for the history of the species.

The influences which govern evolution have recently been stated by two of our great biologists, Jordan and Osborn. They both recognize that in the development of organic life the grip of environment holds.

Jordan,[9] dwelling on the importance of isolation as a factor in evolution, recently wrote:

> Among the factors everywhere and inevitably connected with the course of descent of any species, variation, heredity, selection and isolation must appear; the first two innate, part of the definition of organic life, the last two extrinsic, arising from the necessities of environment, and *not one* of these can find leverage without the presence of each of the others.

Osborn has put the same principle as follows:[10]

> The life and evolution of organisms continuously center around the processes which we term *heredity*, *ontogeny*, *environment* and *selection;* these have been inseparable and interacting from the beginning; a change introduced or initiated through any one of these factors causes a change in all. First, that while inseparable from all the others each process may in certain conditions become an initiative or leading factor; second, that in complex organisms, one factor may at the same time be initiative to another group of characters, the inseparable action bringing about a continuously harmonious result.

These modern statements of the law of natural selection find application immediately as we contemplate the procession of geographies. Change of environment is inherent in the movement of the procession down the ages and, cooperating with intrinsic biotic forces, has caused modification of organisms as a necessary consequence.

Environment as related to any species or to any flora or fauna may be said to be that combination of conditions to which the fauna is adapted and beyond which it can not range into other environments. From this follows the principle: *Except through renewed adaptation, an adapted fauna can migrate only as the limits of its habitat recede, as the area of its environment broadens.*

To apply this principle to the distribution and migration of species or groups of species under the general law of periodicity, we may follow the course of a cycle of changes, from an epoch of diverse conditions through a cosmopolitan state to diversity again.

Diverse conditions of any one geographic state may have been grouped simultaneously to form many environments or faunal provinces, and each of these has then been occupied by its peculiar fauna contemporaneously with more or less unlike faunas in other provinces. Each of these faunas represented an adaptation to the conditions of its peculiar environment. The peculiarities of other faunal provinces surrounding it constituted barriers beyond which the species could not live, or could not rear their young, even if the adults could exist under the adverse conditions. Only within those barriers could those specially adapted species long continue to exist. If their habitat became contracted they also must contract their range; if it shifted or expanded, they might migrate accordingly. And there would be corresponding migration or restriction of faunas which were diversely adapted. Any cause which shifted the conditions of light, heat or food, brought opportunity to some, death to others.

[9] Jordan, David Starr, Isolation as a Factor in Organic Evolution, in "Fifty Years of Darwinism," 1909, pp. 90–91.

[10] Osborn, Henry Fairfield, Darwin and Paleontology, in "Fifty Years of Darwinism," 1909, pp. 238–239.

In the circling changes of geography such an epoch of diversity has been followed by the development of more or less extensive uniformity, according to the periodicity of diastrophism. Let it be assumed that in the course of a long period of quiet, barriers yielded to the monotony of low lands, freely communicating seas, and genial cosmopolitan climates. The factors of evolution were then profoundly generalized. Isolation was replaced by intercourse, adaptation by competitive development and variation, restriction by opportunity. Success lay with him who had the intrinsic capacity to occupy and to hold the widening realm of life. Out of such conditions came cosmopolitan faunas, which exhibit closely similar or identical associations of species even though inhabiting widely separated regions. The identity may be due to *perpetuation of ancestral species,* which have followed up the movement of a favoring habitat; or it may result from evolution of a successful fauna, competent to spread throughout the wide kingdom to which it is born. In the one case the migrants may have lived simultaneously with descendants of the common ancestors in the home province, or the ancestral stock may have died out there before the migration was complete. *The time equivalent or coefficient of migration is indeterminate.* In the second case, that of *indigenous evolution,* the time elapsed while the species spread over an area which was everywhere geographically favorable depended only upon the ability of the migrant and may be assumed to have been brief as compared with geologic epochs. This is the usual assumption. It may be true for appropriate species and periods, but is by no means always true.

Cosmopolitan conditions have been truly world-wide only in exceptional cases. Very extended faunal provinces have been less rarely developed. The Arctic Ocean has been one which repeatedly expanded to include much of Eurasia and America. The girdle of ocean currents which encircled the world in the northern, temperate and tropical zones during Paleozoic, Mesozoic and Eocene times was another such province. Both of these became from time to time the homes of cosmopolitan faunas that existed simultaneously over surprisingly wide realms. At other times they were restricted or divided and faunas became provincial.

If we consider the course of evolution during an epoch when general conditions yielded to provincial environments (excluding the case in which the change is too drastic) the law which applies is Jordan's law of isolation. He uses that term to signify the separation of one or many individuals from others of their kind. The separation implies more or less diversity of environment and consequently more or less unequal or unlike variation along the many possible paths open to the living organism. We conceive a broad life realm, marine or terrestrial, which through subtle changes in the flow of currents of the sea, or of climates of the land, or of depth of waters, or of altitudes above the seas, or of any other condition affecting sensitive organisms, is divided into provinces which offer unlike environments to the descendants of the ancestral cosmopolitan fauna. Adaptation becomes again the dominant process. Being variously conditioned, it leads to variation and the development of different species.

North America represents the facts upon which Jordan[11] founded the law of twin species, which is that:

[11] Jordan, David Starr, Isolation as a Factor in Organic Evolution, in "Fifty Years of Darwinism," 1909, p. 73.

Given any species (or kind) in any region, the nearest related species (or kind) is not to be found in the same region, nor in a remote region, but in a neighboring district separated from the first by a barrier of some sort.

This law, worked out by observation of existing faunas and based on their distribution in our highly diversified lands, owes its recognition to the fact that topography and climate have undergone great changes, and provincial environments have been individualized during the latest geologic periods.

The latest period to which we can assign fairly uniform conditions of climate and moderate relief in North America is the Miocene, and the diversity of environments developed since then is so great that there is reason for surprise at the persistence of geminate species. One might expect differentiation to a degree which would have obscured or obliterated twinship. But it appears that there are provinces in which variations of some ancestral species have not diverged greatly, presumably because conditions within these particular provinces have not undergone any very stimulating or very restrictive change, as regards those species. Such surviving varieties must indeed have existed to a greater or less extent during any such period of changing environments, and the persistence of geminate species must have been a feature of many epochs of diastrophic activity in the past. How long they may have persisted, how slowly or rapidly or impulsively they may have varied, we do not know. *The time relations of geminate species are therefore indeterminate.*

## CORRELATION

*Definition.*—By correlation in paleogeography or geology, I understand that process of reasoning which seeks to demonstrate that certain events of past history occurred simultaneously.

*Contemporaneity.*—In dealing with the enormous time intervals of the earth's history the concept of simultaneous or contemporary events must be liberally grasped. A fair statement is that the phenomena described as contemporaneous shall have existed at the same time within limits of error which do not equal a large fraction of the life of either. Thus we call two men contemporaries when the periods of their active lives coincide, though one may have been born notably later and live longer than the other. But we do not so term a youth and a graybeard, whose living occupies but a few years in common.

It is evident that two long-lived events may differ from near coincidence in time by a larger margin than two short-lived events, and yet be reasonably regarded as contemporaneous. The marine transgression which submerged most of North America during the Cambrian was in a broad sense contemporaneously paralleled by submergence of much of Eurasia; but the moment of arrival of the earliest Cambrian fauna, the Olenellus, which followed the spreading shores over each continent, can not be regarded as contemporaneous at points reached earlier and later in course of the submergence.

The evidences of contemporaneity are both inorganic and organic, but, though we are wont to classify them thus in two distinct categories, they are most intimately related through that principle of periodicity, which is at the bottom of all terrestrial phenomena. Diastrophism is periodic, all changes in the inorganic as in the organic are conditioned by that periodicity, and all such changes are therefore themselves periodic. Moreover, the physical and biological phenomena are linked in a continuous chain of cause and effect, which stretches from gravity and internal heat at one end to life at the other, and which

tends ever to vibrate in harmony. Whatever disturbs the equilibrium of any part, affects the whole. Diastrophism initiates change. The sun's energy modifies the resulting surface features, and physical, chemical and biotic reactions carry the effects into all the phenomena of nature. Were nature unchanging, time would pass unrecorded. It is through the sequence of unlike *effects* that we may establish a chronology, and that sequence begins with diastrophism as the initial cause and ends with evolution as the final effect.

DIASTROPHISM THE BASIS OF CORRELATION

It follows logically from the preceding that the initial cause of change, diastrophism, is necessarily the ultimate basis of all correlation. Chamberlin[12] has very recently put this conclusion strongly and clearly.

On a preceding page the law of periodicity of diastrophism is stated as deduced from the observed occurrences of diastrophic movements in different dynamic provinces. According to that law it is *inactivity, rather than activity,* of earth movements, which has contemporaneously characterized the whole earth. That is to say, the normal condition of the stresses and resistances in the earth's crust is a close approach to equilibrium, and disturbances of that equilibrium have in general been manifested at the surface by slight movements only. More emphatic movements have been relatively occasional and provincial (circum-oceanic), and we may add that they have been more restricted and less prolonged as they have been more vigorous.

This law governs the relation of diastrophism to correlation.

The long eras of inactivity, the base-level eras for the whole world, have been essentially contemporaneous, though not conterminous or even approximately conterminous. But their very great duration, from which their essential contemporaneity results, unfits these eras for any except the broadest outline of classification, so far as they themselves are concerned. Yet the topographic, climatic and environmental uniformity which developed during these eras of inactivity affords the best conditions for correlation by other criteria. Thus the base-level eras are to the history of paleogeography what the broad and deep foundations of a great building are to the many rooms of the superstructure.

Thus for inactivity. The periods of activity present different phenomena, differently distributed in place and time. We may define a period of activity as comprising that time which is marked initially by decided continental movements and culminates in notable orogenic uplifts. Pennsylvanian and Permian constituted such a period about the North Atlantic, as witness the development of lands, mountains and sediments in western Europe and eastern North America. The recognized active periods appear to characterize distinct dynamic provinces which are ocean basins, as already described. Thus with regard to their value in correlation we may say: *Periods of active diastrophic movement have been shorter than eras of base-leveling, and consequently define time divisions, which are more nearly commensurate with those of current geologic standards.* They are, however, still long, and their value is in broad fundamental classification.

Diastrophic activity is, moreover, contemporaneously manifested only in and around the dynamic province in which it originates. During any particular period it has been peculiar to a particular oceanic basin or group of basins and has disturbed

[12] Chamberlin, T. C., "Diastrophism the Ultimate Basis of Correlation," *Jour. of Geol.*

only the continental masses adjacent to that basin or basins. The value of periodic activity in correlation is thus conditioned by the regional distribution of diastrophism.

Continents bordering on one and the same dynamic province have usually been disturbed during one and the same period. Opposite sides of one and the same continent, however, bordering on different dynamic provinces, do not exhibit similar conditions of disturbance at the same time.

Western Europe and eastern North America, for instance, exhibit parallel diastrophic histories, peculiar to the North Atlantic basin, but the diastrophic histories of the Atlantic and Pacific sides of North America do not run parallel.

Any great period of diastrophic activity, though relatively short as compared with an era of inactivity, is very long in comparison with any particular movement incidental to its own development. Thus Pennsylvanian and Permian diastrophism had a long history before the folding of strata occurred in the Appalachian trough. Such an incident of folding, or of any orogenic growth whatever, is locally conditioned. It results from local structures and localized pressures. The time of disturbance depends upon the local position of the district in relation to the source of disturbing stresses, and is peculiar to the district. The phenomena of folding, or of orogenic growth, therefore, do not afford criteria for correlation beyond the area of special conditions. We may not safely correlate the displacement of the Appalachian zone with the disturbance of the Carboniferous in England, for instance, although both events occurred during the same diastrophic period and belong to one and the same dynamic province.

Within any *orogenic district,* the epoch of general disturbance is a principal element of classification. It is set apart, it is unavoidable. It must be recognized, and it commonly separates major divisions.

This stated, it is none the less of the first importance to insist on the local character of the criteria. A district of orogenic disturbance is sharply limited by mechanical conditions. Across the line exist other conditions, which are inconsistent with orogeny and its manifestations. The criteria of correlation by orogeny fail, therefore, beyond the line. Disturbance and quiet, erosion and continuous deposition, unconformity and conformity, have developed simultaneously in immediately adjacent districts many times.

In strong contrast to continental and orogenic movements, which develop subaerially, are those subsidences which occur beneath the oceans. Though they also are more or less local, their effects are practically world-wide, for any submarine movement modifies the capacity of ocean basins and changes the position of sea level on all coasts. No other phenomenon is so nearly simultaneous.

If any one of the confluent ocean basins be deepened the sea level datum about all lands must be lowered. The effect may not be evident in the exceptional case that any land subsides by a due amount; but the exceptional case is not likely to mask the general effect of a universal ebb tide. Shallowed and reduced epicontinental seas, low islands and low coastal plains mantled with the latest sediments, slight erosion and unconformity without disturbance of the strata, constituting a general condition of continents, these are the characteristic phenomena of such an ebb. They distinguish the middle Ordovician of regions as remote as eastern North America, eastern China and western Europe. They mark also the passage from Cretaceous to Eocene.

Suboceanic movements have no doubt

occurred, especially during periods of pronounced continental deformation, but also during eras of quiescence on lands. Their effect upon sea level is, however, readily confused or masked by local uplift or depression and is, therefore, of little value when these become decided. During base-level eras the conditions for recognition are most favorable and the occasional occurrence of a world-wide ebb constitutes the most exact measure of contemporaneity by which we may correlate.

The several groups of diastrophic phenomena which have been outlined furnish the fundamental basis of classification and correlation. They are obviously very unequal in scope, character and value. Their geographic range may embrace the sphere, or fall within the realm of an ocean, or be no more extensive than a mountain district. Their duration may equal a vast era, or merely a period, an epoch or even only an episode. But all other phenomena are dependent and sequential. Diastrophism sets the stage and marks off the acts of the earth drama.

### ORGANIC CRITERIA OF CORRELATION

I turn now to those criteria of correlation which are most universally employed, the criteria of organic evolution.

All paleontologists and geologists who are familiar with the geologic side of their science, as distinguished from the biologic, are convinced of the influence of environment on evolution; and they consequently recognize the dependence of species in regard to origin, development and distribution, upon the geographic conditions of their period of existence.

These extrinsic conditions have been by no means uniform from place to place or from time to time; they have varied periodically, and their influence upon life has differed in kind and degree according to the period. As has been emphasized by Chamberlin, marine life has at certain times been favorably conditioned by admission to broadening epicontinental seas, and alternately unfavorably conditioned by limitation to narrowed habitats on the margins of continental shelves. With similar effects terrestrial life has ranged over wide and connected continents under genial climates or has been confined to provinces of sub-continental or even smaller dimensions.

Marine life, when favored by extended domain, has also enjoyed genial and largely uniform environment. Shallow, freely communicating waters, traversed by continuous far-circling currents, offered uniformity. Barriers, whether of lands, or temperature, or sediment, or salinity, did not persist in marked degree at such times. Pressing against the shifting boundaries of his ancestral habitat, the marine migrant could advance as the limits receded, *no faster*, and thus a species fitted to compete in the occupation of new territory could spread from the provincial to the cosmopolitan with the corresponding spread of that environment to which it was adapted.

Assuming that the species persists during this time with only such variation as might be consistent with identification, the distribution will correspond to the spread of environment. The obvious fact is the presence of the species, or of the fauna, of one locality in another place also. The inconspicuous, but all-important fact is the control by the geographic factor, which has in any particular case determined a shorter or longer interval of migration. The migrants were descendants, who wandered as they could. That they could wander farther than their ancestors was due to a spreading sea, to the sweep of a marine current across a vanishing isthmus

or shallow, to a chilling or warming or other physical change, often as fatal to one fauna as it was favoring to another. The controlling factor was geographic; it set the hour of immigration; and through knowledge of it alone can we estimate the time elapsed during the wandering.

The case stated is that of passage from diversified to unified environments. It has repeatedly characterized geologic periods; and it has repeatedly culminated in the evolution and distribution of cosmopolitan faunas, which simultaneously peopled remote realms with like species. The coefficient of uncertainty, with which we must qualify any correlation that depends solely on identity of species, is reduced to a minimum at the time of culmination of uniformity.

Uniformity has in turn repeatedly yielded to diversity. Large marine faunal realms have been divided into provinces by emergence of continents, by diversion of ocean currents, by differentiation of climates, by local dilution or concentration of ocean waters and by the other changes which establish physical barriers. Lands have been diversified in like manner. In each such province evolution re-began by extinction of the unadapted and survival of the fitter forms. Originating in a common ancestry, the faunas of two neighboring provinces may for a time have had much in common. As they developed differences, Jordan's law of geographic isolation came into play. The resulting geminate species may have been closely contemporaneous; but continued contemporaneity depends upon uniform rates of differentiation, which the changing environments do not favor. Several relations, other than uniformity, are conceivable; isolate a fauna under static conditions and contrast it with the same fauna under changing conditions. Assume the changes to be favorable or unfavorable to the indigenous fauna. Contrast isolation with more or less free emigration and immigration. Consider the many factors of environment and the many possibilities of variation in sensitive, highly developed organisms.

Must we not conclude that diversity of species rather than likeness will be the rule at such a time among contemporaneous faunas?

But it is upon likenesses that we rest our faunal correlations. What do they signify? Simply that the surviving species of a fauna have remained unchanged during a longer or a shorter period, either at home or during migration, or that variations have developed similarly in two provinces from an ancestral stock similarly conditioned.

When we find a German fauna in New York or a Russian fauna in western North America, the occurrence means that the particular fauna persisted in an environment which offered it no stimulus to variation during the period of migration from the ancestral home to the new domain. But that period remains indeterminate. It was the shifting of the habitat that made the migration possible and that set the rate of progress. It was a geographic movement first and the faunal journey was a consequence.

Or in case of similar variations from an ancestral stock, can we assume that the stimuli acted in different provinces at the same times and at the same rates? When they did, but only when they did, were the similar variations contemporaneous; and the cases of such coincidence may reasonably be regarded as exceptional.

Hence I conclude that:

*Correlation by identical or closely related species, faunules or floras is subject to a coefficient of error, which is a function*

*of the geographic changes of the particular period and of the geographic conditions that preceded.*

*The coefficient may be placed at a minimum, which is possibly negligible, at times of established cosmopolitan relations; but it rises to a quantity which we can not neglect at intervening periods of physical change.*

The emphasis here placed on the geographic factor in correlation should not obscure the initiative part played by the life principle. It is the evolutionary force; its energy and the direction of its action depend upon the kind of organism. But the conditions of its action, its rate and the result depend upon environment at any instant and upon environmental change in the long run.

SUMMARY

The broad general principles of paleogeography, which I would cite as most fundamental, are as follows:

1. Ocean basins are permanent hollows of the earth's surface and have occupied their present sites since an early date in the development of geographic features. This principle does not exclude notable changes in the positions of their margins, which on the whole have encroached upon continental areas.

2. Superficial oceanic circulation within the permanent oceans has persisted since an early stage of their existence, essentially in the great drifts which it now follows under the trade winds. It is probable that the present deep circulation of oceanic waters, poleward at the surface and equatorward below the surface, is due to exceptional refrigeration at the pole, and has been preceded during past ages by a prevailing reversed movement of warm saline waters from the equator in the depths and cool less saline waters from the poles on the surface.

3. Diastrophism has been periodic. Viewed according to the periodicity of diastrophism, the earth's history falls into cycles, and each cycle into two periods, one of inactivity and another of activity. The periods of inactivity have been long, and during a major part of the duration of any such period the condition of inactivity has been common to the entire surface of the globe. Inactivity has not been coterminous, however, in different regions.

The periods of diastrophic activity have been relatively short, and as regards the whole surface of the earth in general not contemporaneous. The great ocean basins are distinct dynamic provinces, and each has experienced periods of diastrophic activity peculiar to its individual history. Orogenic districts are sharply limited by local mechanical conditions. The epochs of organic deformation are relatively brief. And folding and unconformity, therefore, are frequently not contemporaneous even in one and the same dynamic province.

4. The processes of erosion, sedimentation, chemical activity and organic evolution have been periodically conditioned according to the periodicity of diastrophism. The corresponding physical phenomena (relief, deposits and climate) exhibit rhythmic changes which repeat similar conditions in like associations. Organic forms, both faunas and floras, evolving through intrinsic vital energy but not repeating, have been rhythmically conditioned by changing environments.

5. Erosion has been constant on land surfaces through the activity of some of the sub-processes, decay, denudation or aggradation, which have never failed to make a record. A fossil sub-aerial surface must always show the record, unless it has been obliterated.

6. Marine sedimentation has sometimes been inconstant. During periods of dias-

trophic activity, when lands have been high, epicontinental seas small, and marine currents largely confined within deep ocean basins, sedimentation has been dominant. But during periods of diastrophic inactivity, when lands have been low, epicontinental seas extensive, and marine currents active on shallows and straits, sedimentation has failed in consequence of non-deposition or marine scour in appropriate situations.

7. The criteria of correlation are both physical and organic. The physical facts are basal. The organic forms, though endowed with evolutionary energy, are dependent and sequential. Any ultimate classification of the earth's history must be founded upon all the phenomena, interpreted through their relations in the chain of cause and effect from diastrophism to life.

BAILEY WILLIS

## A NATIONAL BUREAU OF SEISMOLOGY

AT its last annual meeting, the American Philosophical Society showed its interest in the scientific investigation of earthquakes by devoting an entire session to their consideration. At the close of the session the following resolutions were unanimously adopted:

WHEREAS, Earthquakes have been the cause of great loss of life and property within the territory of the United States and its possessions, as well as in other countries, and

WHEREAS, It is only through the scientific investigation of the phenomena that there is hope of discovering the laws which govern them, so as to predict their occurrence and to reduce the danger to life and property, and

WHEREAS, Such investigations can be successfully conducted only with the support of the general government, be it, therefore,

*Resolved*, That this society urge upon congress the establishment of a national Bureau of Seismology, and suggest that this bureau be organized under the Smithsonian Institution with the active cooperation of the other scientific departments of the government and that this bureau be charged with the following duties:

*a*. The collection of seismological data.

*b*. The establishment of observing stations.

*c*. The organization of an expeditionary corps for the investigation of special earthquakes and volcanic eruptions in any part of the world.

*d*. The study and investigation of special earthquake regions within the national domain. And

*Resolved*, That copies of these resolutions be transmitted to the President, to the President of the Senate, to the Speaker of the House of Representatives and to the Secretary of the Smithsonian Institution.

Through the active interest of Dr. W. W. Keen, the president of the society, these resolutions were brought favorably to the attention of congress, and were in the House of Representatives referred to the Committee on Library, of which Honorable Samuel W. McCall, of Massachusetts, is chairman. The other members of the committee are E. L. Hamilton, of Michigan; Charles H. Burke, of South Dakota; William H. Howard, of Georgia, and Charles R. Thomas, of North Carolina.

Mr. McCall has already shown his appreciation of the importance of the subject, and it is hoped that readers of SCIENCE will lose no opportunity to urge upon their senators and representatives in congress the need of establishing such a bureau as is proposed, and to set forth the backward position of our government in this important matter as compared with foreign countries, though otherwise generously disposed towards scientific investigation.

There is already some danger that the matter may be disposed of through a small appropriation to some existing bureau, where the lack of special interest in the subject would soon result in the investigations being crowded out to make way for others which appeal more directly to the administration of the bureau.

WM. H. HOBBS

UNIVERSITY OF MICHIGAN

## SCIENTIFIC NOTES AND NEWS

THE national testimonial to Commander Robert Peary at the Metropolitan Opera House on February 8 was most enthusiastic, the house being completely filled. Governor